
OLFACTION AND THE FUNCTION OF THE PARANASAL SINUSES

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To know what you know
and what you do not know,
that is true knowledge.
Confucius

On a trip to the Luangwa valley, I watch the herds of animals interacting in what must be close to their original habitat, as it has existed for millions of years.

A large herd of zebra is grazing calmly on the succulent new grass recently sprouted after the first rains of the season. They are seemingly unconcerned and unstressed by a small group of lions lazily lounging in the meager shade of a flat-topped acacia.

After a while, one of the lions starts to get hungry and begins to gaze longingly over the striped smorgasbord grazing almost within reach. Lions are by nature lazy, so it takes the lion some time to make up its mind, but eventually he gets up and ambles towards the grazing zebras, that continue grazing calmly until the lion is almost upon them. Then there is suddenly an all-out panic and they all gallop away in the opposite direction of the lion, who must set off in a sprint after them in an attempt to catch his lunch. How do the zebras know which direction to run if the grass is high and only those at the edge of the herd can actually see the lion before it is too late? Some of the very young zebras will sometimes gallop in the wrong direction, but the majority will head in exactly the right direction to put as much distance between them and their predator as possible.

Obviously olfaction must play an important role, since while grazing it is difficult to keep a constant look out, and the high grass usually obstructs much of the view. Fortunately for the zebras, a lion being a carnivore, is not the cleanest of animals, and can often be smelled a proverbial mile off even with our rudimentary sense of smell. In fact all the zebras in the herd will have smelled the lions the whole time they were grazing near them, and yet they continued unconcerned and until one of the lions made a consistent move in their direction.

The zebras seem to know the exact moment when the lion starts ambling towards them, perhaps he is whistling an inaudible tune under his breath, studiously avoiding eye contact, for every lion knows you must never make eye contact with a victim... they sense the exact moment the lion draws close enough to sprint after them.

Somehow the zebras' olfactory system registers the subtle and continued increase in lion-scent particles per million, and this is where the paranasal sinuses come in.

There have been speculations about the function of the sinuses since they were first recognized during anatomical dissections, and a number of possible theories are regularly mentioned; despite an alarming lack of evidence or even intuitive common sense in favor any of these theories.

The sinuses are air filled bony spaces in the face connected to the nasal cavity by narrow channels and have been variously proposed to:

- lighten the weight of skull and head
- function as a compression zone in facial trauma
- warm and moisten the inhaled air (air conditioning)
- function as echo chamber for the voice
- provide heat insulation of the brain
- act as a flotation device in water
- all of the above

It is of course always possible that they have no function at all (apart from, some cynics might add, helping otolaryngologists to avoid starvation), but since these air spaces occur in most mammals as well as in many birds and reptiles, we could invoke the evolutionary maxim of 'use it or lose it' and assume they probably have some essential function(s), and that it is a common function for a wide range of animals.

The existing theories are fairly easily discounted using only a modicum of anatomical knowledge:

—In *Homo sapiens* the combined volume of the paranasal sinuses is approximately 50 ml, so weight saving would be less than 50 grams and a mouth full of water would be almost as heavy. The gnu and buffalo grazing alongside the zebras on the African highlands, as herbivores having larger sinuses, their weight savings are still negligible compared to the various kilograms of horns they sport for an occasional joust with a sexual rival.

— While for the human face the sinuses may function as a compression or crumple zone for blunt trauma (though it is difficult to imagine an evolutionary setting in which that might have been consistently applied), for most animals the sinuses are at the back of the nose and not usefully located for compression in case of trauma due to perhaps running into a

tree while trying to escape the lion. It is debatable if that would give sufficient advantage to escape from being eaten and removed from the gene pool. Sufficient trauma to collapse the sinuses would certainly incapacitate a person or an animal long enough to allow the lion to pounce.

— The air conditioning function of the sinuses might be credible if it were not for the simple anatomical fact that normal sinuses are lined by only a very thin mucous membrane layer with none of the extensive vascular network that would be required for both cooling/heating and moisturizing of inhaled air. The nasal turbinates, with their abundant blood supply seem to fill that function admirably without the help of the sinuses. Besides, the existence of sinuses in cold-blooded animals also tends to discount this theory somewhat.

— To assume that the sinuses developed as a vocal echo or resonance chamber, is reversing developmental sequence, for the voice and speech developed millions of years after the sinuses, and many animals with large paranasal sinuses are mute or almost mute.

— Were the sinuses designed for insulation of the brain you would expect them to be more evenly distributed around the skull. Curiously, the giraffe has a very extensive sinus system covering most of the skull, and a theory has been advanced that they require the extra air-conditioning as their heads are closer to the sun than most other mammals on the African savannah. I will not even comment on this.

—A lung full of air is a far more effective flotation device than 50 ml of air in the sinuses. A 1,000 kg buffalo is unlikely to keep its head above water only by 500 ml of air. This theory should be fairly easy to discount by observing if swimmers with sinusitis or catarrh tend to sink.

On the whole the *scientific* evidence in favor of these theories ranges from not very good to non-existent, and in many ways it is surprising that these theories continue to be cited in most textbooks and courses that clearly do less than they should to try and stimulate critical thought processes in the reader.

What we know about the sinuses is the following: they are bony air filled spaces connected to the nasal cavity by only a narrow channel. They exist in a large array of animals, and seem to be larger in herbivores than in predators. They open into the roof of the nose near the olfactory mucosa, and in some animals are partially lined by olfactory mucosa.

With olfaction being one of the important functions in this anatomical region, the question arises if there could be some relationship with olfaction, a consideration not previously contemplated in the various theories proposed.

Even in man, where olfaction has been relegated almost to last place in the sensory ranking, it continues to be a far more important modality than

we realize, influencing our behavior, from eating to sex, in a multitude of subtle ways we are not even aware of. We no longer depend on olfaction for our survival (except on rare occasions of fire, rotten food or toxic fumes) but for many animals olfaction is essential. You have only to observe a pet dog savoring the delectable bouquet of scents on a random lamppost to realize we must be missing out on something. The zebra being stalked by lions and hyenas would soon disappear from the genetic pool if they were not warned by its olfactory system. Frequently grazing in close proximity to various predators, its peace of mind depends on the ability to determine if the lion is slowly drawing closer, or only stretching its weary limbs after a siesta.

Obviously, the scent would become stronger as the lion draws gradually closer, but there are several problems; respiration, also via the nose, draws air and aromatic molecules inwards towards the lungs, then out again. Since many of the inhaled molecules are trapped by the respiratory mucosa, the expired air has for the zebra a far lower concentration of lion-specific molecules. The molecules need to diffuse through the mucous layer to be detected by the olfactory nerve endings, so there is some delay levelling of the olfactory response. It may be difficult to determine from this continued ebb and flow of subtle molecules just how close the predator is getting. They therefore need a reference against which to compare the incoming air.

Our proposal is that the paranasal sinuses function as such a reference, and that conversely the function of the paranasal sinuses is to provide such a frame of reference; a reservoir of background levels of various aromatic molecules in the immediate environment.

Through the narrow channels, air gradually diffuses into the sinuses where the air is held in relatively quiet backwater reservoirs away from the turbulent respiratory flow and diffuses out again to provide a fairly constant level of aromatic molecules near the olfactory mucosa. As already mentioned, in some animals olfactory mucosa has been identified in the sinuses, and that would provide an even more accurate sensor of background molecules compared to in- and ex-haled molecules. Against this background reference, the animal's central nervous system can calculate accurately if a predator (or in other cases the prey) is getting closer or more distant, and at what precise moment the flight (or fight) mechanisms must be brought into play.

Like all other theories this is of course all pure speculation. How would you go about proving this to the satisfaction of discerning scientific observers and reviewers? Have any of the other theories seen a serious attempt at scientific confirmation or are they urban myths thrown up over the years and 'accepted' by force of relentless repetition, or what we may

call the *snark effect*, as described by Lewis Carroll in his marvelous poem "The hunting of the snark": "*What I tell you three times is true.*"

It is not easy to find an experimental model to corroborate or refute this theory for the olfactory system is notoriously subtle and does not give up its secrets willingly. While 150 years ago Claude Bernard emphasized that every investigation begins with an Idea; and he was able to sacrifice 21 dogs in his quest for the function of the pancreas, experimenters today would not be keen and ethical committees now would be unlikely to permit such experimentation on large animal models.

Possibly we might examine olfactory responses in patients with chronic sinusitis, but there also it is difficult to confirm both the response and the continued obstruction of the sinuses (without repeated scans that are essentially unnecessary for the patient).

However, chance does tend to favor the prepared mind, and it is possible that serendipity may help to confirm or reject a theory.

These days when all the answers seem to be available everywhere for the picking, it often comes as a shock to realize that that what we do not know still remains infinitely greater than what we do know.